Recurrence Interval for the 2006 Flood
Delaware and Otsego County, New York

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Ouleout Creek, flood scars

2 ½ days of heavy rain in central New York on Radar

Periods of rain came in waves

Much of the humidity was of tropical origin

On June 28, a tropical wave moved up the coast. Its rain was intensified by the cold front.
Otego Creek in Laurens, NY
Floods caused erosion of cropland
Significant transport of cobbles and boulders

Several questions must be raised:

• How often will a flood like this come along?
• Will we be better prepared next time?
• What can we learn from these floods?
  – What areas were most damaged?
  – What areas were least affected?
  – This was a “geomorphic” event. Can we learn something about erosion, transport, and deposition from this event?
There is a lot of basic research to do here!

- Get a better handle on flood recurrence
- Quantify relationships between rainfall and runoff
- Characterize flood heights and channel characteristics (how rough is the bed?)
- Document erosion, transport, and deposition in a range of settings
- Today, I’ll start with flood recurrence
Flood Recurrence

• Rivers are always “there”, but
  – Discharge varies by orders of magnitude in a given year
  – And occasionally, a big flood occurs…

• The frequency-size distribution for all of the flows a river experiences would be very helpful to know

• Quantitative records rarely span more than 50-60 years
Modeling flood frequency distributions

• Log-normal distribution (Log Pearson Type III)
  – Use average, standard deviation, and skew of log transformed data, get a frequency factor from a table, then find the discharge for a given recurrence period; it’s not simple…

• Power Law distribution (more on this later…)
A note on flood frequency distributions: Real flow distributions do not fit any known mathematical distributions perfectly well; the USGS recommends the Log Pearson Type III distribution, but they do so with a nod to future changes (USGS Circular 17b, 1982)
Log Pearson Type III Distribution

• This is the statistical numerical model that is fit to the distribution of flow events

• Link to OSU’s Excellent tutorial site for computing river flow statistics
  http://water.oregonstate.edu/streamflow/

• Link to USGS’s site where they detail the method for determining flood recurrence
  http://water.usgs.gov/osw/bulletin17b/bulletin_17B.html
From the log \((Q)\) distribution, we can find...

- The average \((\mu)\)
- The standard deviation \((\sigma)\)
- The skew (asymmetry of the distribution)
- With these values, we can reconstruct the distribution with an equation, the Log Pearson Type III distribution

\[
\log (Q) = \mu + K \sigma
\]

where \(\mu\) is the average of \(\log (Q)\), \(K\) is the frequency factor that depends on recurrence interval and skew of \(\log (Q)\) [and you get it from a table of values], and \(\sigma\) is the standard deviation of \(\log (Q)\)

- From this equation, we can estimate the frequency of flows of a given size
Shaded Relief Map of USGS Gage Stations
Recurrence Intervals Using Log Pearson Type III

- Susq-R, Unadilla
- Unadilla River, Rockdale
- Ouleout Creek, Sidney, NY
- W. DE-R, Delhi
- Little DE-R, Delhi
- Trout Creek
- Wolf Creek
Power law distribution (fractal)

- Many events in nature have lots of small events and few large ones (earthquakes, fault sizes, floods)
- These distributions are self-similar—we can use one part of the distribution to describe any other part
  - They look the same at any level of magnification
- A power law mathematical model describes such events
  - Order the flows and compute recurrence intervals
  - Fit a power law equation to the data

General form of a power law

\[ y(x) = ax^b \]

where \( y \) is the dependent variable
\( a \) is a constant coefficient; think of this as a unit scale (at \( x = 1 \))
\( x \) is the variate

and \( b \) is the exponent which characterizes the rate of change of \( y \) vs \( x \)

for instance, as \( b \to 0 \), \( y \) doesn't vary with \( x \)

if \( b > 0 \), then \( y \) increases with \( x \)

if \( b < 0 \), then \( y \) decreases with \( x \)
Method to use a power law to model recurrence intervals

- Sort the data by size, largest to smallest
- Rank each event \(m\), from 1 (the largest) to \(n\) (the smallest)
- Determine the probability \(P\) that a flow of a given size will be equaled or exceeded:
  \[ P = \frac{m}{n+1} \]
- The reciprocal of \(P\) is the recurrence interval \(RI\), the size of flow that comes along once in the time interval (years, in our situation)
  \[ RI = \frac{n+1}{m} \]
- Plot the discharge vs RI
- Fit a power law trend line to the data
Power law flow distribution

West Branch Delaware River at Delhi, NY
Peak Annual Flow

Note: Each gage record exhibits the same form as above, but with different exponents and coefficients in the power law relation

y = 2986x^{0.375}

Note: the “low end” less than 1.4 year RI has been omitted
Comparing LP3 and Power Law fits to the data

Peak Annual Flow at the West Branch Delaware River at Delhi, NY

$y = 2986x^{0.375}$
Recurrence Intervals using LPT3 and Power law models

<table>
<thead>
<tr>
<th>River</th>
<th>Peak Discharge (cfs)</th>
<th>Recurrence Interval, LPT3</th>
<th>Recurrence Interval, Power Law</th>
</tr>
</thead>
<tbody>
<tr>
<td>Susquehanna River, Unadilla</td>
<td>34,900</td>
<td>121 years</td>
<td>48 years</td>
</tr>
<tr>
<td>West Branch Delaware River, Walton</td>
<td>28,600</td>
<td>67 years</td>
<td>32 years</td>
</tr>
<tr>
<td>Unadilla River, Rockdale</td>
<td>23,100</td>
<td>167 years</td>
<td>70 years</td>
</tr>
<tr>
<td>West Branch Delaware River, Delhi</td>
<td>13000</td>
<td>208 years</td>
<td>51 years</td>
</tr>
<tr>
<td>Ouleout Creek</td>
<td>7250</td>
<td>76 years</td>
<td>43 years</td>
</tr>
<tr>
<td>Little Delaware River at Delhi</td>
<td>6100</td>
<td>141 years</td>
<td>50 years</td>
</tr>
<tr>
<td>Trout Creek</td>
<td>4350</td>
<td>54 years</td>
<td>25 years</td>
</tr>
<tr>
<td>Wolf Creek</td>
<td>350</td>
<td>23 years</td>
<td>12 years</td>
</tr>
</tbody>
</table>

Note: these are all model dependent approximations, and should NOT be considered an official estimate for planning purposes
Bottom line on the 2006 Flood event

- The 2006 Flood is probably a once-(or twice)-in-a-lifetime experience
- Recurrence intervals vary with drainage basin size (smaller basins exhibit larger ranges)
- The official USGS Flood Recurrence model for computing flood recurrence is the Log Pearson Type III distribution (USGS acknowledges it has weaknesses)
  - For the 2006 Delaware County flood, LPT3 gives longer return periods than the power law
- The power law distribution for flow events is gaining favor among some hydrologists
  - It is simpler to develop recurrence models for ungaged catchments from the power law diagrams, via drainage basin area